1 Description, Types, and Prescription of the Exercise

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Abstract

Hippocrates wrote in 1931 that "eating alone will not keep a man well; he must also take exercise." Since then, the impact of these two concepts on healthy life has never changed.

Exercise is a very powerful tool, even medicine, in reducing harmful effects of chronic diseases and mortality rates, as well as in treating and preventing chronic diseases. There is a linear relationship between activity level and health status. People who lead an active and fit lifestyle live longer and healthier. In contrast, physical inactivity has a mind-boggling array of detrimental effects on health. Sedentary people are affected by the chronic disease early and die at a younger age as they do not adapt exercise/sports to their lives. This relationship between illness and a sedentary lifestyle affects all age groups, albeit in varying degrees: children, adults, and the elderly. Current studies show that people with active lifestyles are much healthier. It would not be wrong to say that inactivity, a problem that can be solved by movement, is the biggest public health problem in this era.

In this section, the description, types, and prescription of the exercise that should be done regularly both in illness and health will be explained.

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1.1 Exercise and Physical Activity

There is confusion in the definition of physical activity, exercise, physical fitness, and sport. Let us take a look at the differences between these terms.

1.1.1 Physical Activity

It is any movement involving the work of the skeletal muscle(s) that expends energy (calories). Physical activity may include housework, stair climbing, general chores, walking, gardening, or other activities during the day involving movement. Being physically active for at least 150 min a week reduces the risk of disease and improves the quality of life. The term to describe the amount of physical activity is *dosage*. For exercise or physical activity, dose refers to the amount of physical activity performed by a person or participant. Three components determine the total dose or amount of activity: frequency, duration, and intensity. Let us detail the components of physical activity: (1) *Frequency* is usually

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expressed as sessions, episodes, or bouts on a daily or weekly basis; (2) *Duration* is the amount of time you spend participating in one session of physical activity; and (3) *Intensity* is the rate of energy expenditure required to perform the desired aerobic activity or the magnitude of the force applied during resistance exercise.

1.1.2 Exercise

It is also a type of physical activity. It is planned, structured, and used to improve aspects of physical fitness. The intensity, duration, and frequency of exercise are typically used to measure progress and improvements. In other words, for us to call a physical activity as exercise, it must have a specific purpose or goal, and it must be structured, planned, and repeated. During exercise, you engage in an organized movement for a certain period. This could be running, jogging, jumping rope, lifting weights, swimming, or cycling. Exercise can be planned with many goals such as being healthy; looking beautiful; losing weight; improving body composition; reducing stress; improving blood sugar; lipid or blood pressure control; improving muscular strength, power, and endurance; increasing mental and memory capacity; and improving cardiovascular capacity. Another definition that should be emphasized here is exercise training. "Exercise" and "exercise training" are often used interchangeably and generally refer to physical activity performed in leisure time to improve or maintain physical fitness, physical performance, or health.

1.1.3 Physical Fitness

It refers to the ability of multiple systems in the body to work together to perform certain tasks. The health-related components of physical fitness are collected under five parameters, each of which can be measured by specific tests: muscular strength, muscular endurance, cardiorespiratory fitness, flexibility, and agility.

1.1.4 The Sport

It encompasses a set of physical activities performed within a set of rules and performed as part of leisure or competition. Sports activities often involve physical activity performed by teams or individuals and are supported by an institutional framework such as a sports agency.

1.2 Types of Exercise

Various types of exercise can be used to improve the components of physical activity. These exercises and their effect on physical fitness are summarized in Table 1.1.

1.2.1 Aerobic Exercises

1.2.1.1 Types

Any activity that uses large muscle groups, is sustained, and is rhythmic can be considered aerobic exercise. In general, low-skill aerobic exercises should be included in exercise prescriptions to improve physical fitness. Aerobic exercises that require the least skill and can be easily modified to suit individual physical fitness levels include brisk walking, cycling, swimming, aerobic exercise in water, and slow dancing. Aerobic exercises that are performed at a higher intensity and therefore recommended for people who exercise regularly include jogging, step exercise, fast dancing, and elliptical exercise. Aerobic exercise/activity causes a person's heart to beat faster and breathe more intensely than usual. "*Cardio*" is a

Table 1.1 Exercise types and their effects on physical fitness

Types	Effects
Aerobic	Improves body composition and cardiorespiratory fitness
Strengthening	Improves strength, power, and endurance
Flexibility	Improves flexibility
Neuromuscular	Improves balance, coordination, agility, and proprioception

training ground that offers an unlimited variety of exercises: walking, running, cycling, cross-country skiing, swimming, and dancing. Anything that gets the heart rate above the resting heart rate is *cardio*. However, there are different categories of *cardio*, both aerobic and anaerobic. The most commonly used cardio exercises in clinics are as follows:

Steady-State Exercises (Aerobic)

This type of cardio refers to the pace of the workout and can include any level of intensity. As the name suggests, the goal is to maintain a steady pace and intensity throughout the entire duration of the preferred workout.

Low- and Moderate-Intensity Exercises (Aerobic)

Low-intensity exercise can be defined as any exercise that keeps the heart rate below 50% of the maximum heart rate such as brisk walking or slow cycling. Moderate-intensity exercises keep the heart rate between 50 and 70% of the maximum heart rate. During moderate-intensity exercise, breath control is very important. Thus, care should be taken to ensure that the patient can speak without shortness of breath during exercise.

High-Intensity and Interval Exercises (Anaerobic)

These exercises keep the heart rate at or above 70% of the maximum heart rate. High-intensity exercises include sprinting, some types of resistance training, and high-intensity interval training (HIIT). Intervals are the division of exercises into several segments (i.e., repetitions) and completion as part of the same exercise (i.e., one round). They can be divided into many formats, but the most common is time or distance blocks.

Intervals should usually be designed as lower-intensity movements like walking or resting between high-intensity exercises like sprinting or jumping rope. Here is an example design for the high-intensity training-to-rest ratio: *Initial (ratio: 1/2)*: One unit of high-intensity training interval followed by two more units of low-intensity training interval allows the body to recover before returning to that higher-intensity interval. *Intermediate-to-advanced athlete (ratio: 2/1)*: Twice the time or repetitions are split into high-intensity training intervals, half of which is split into rest intervals: Two units of high-intensity training interval followed by one unit of lower-intensity training interval/rest.

In general, endurance training models designed with HIIT consist of a combination of different training sessions arranged periodically on time scales ranging from micro-cycle (2–7 days) to mid-cycle (3–6 weeks) to macro-cycle (6–12 months; including preparation, competition, and transition periods) (Fig. 1.1).

1.2.1.2 Dosage

The dose of aerobic exercise consists of the frequency (*F*), intensity (*I*), duration (time, *T*), volume (*V*), and progression (*P*) of the exercise

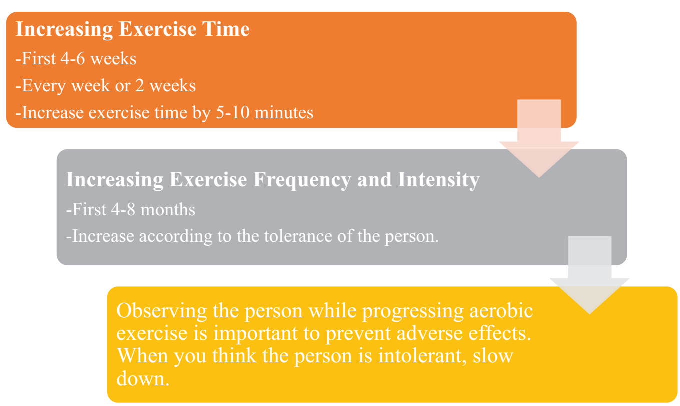

Fig. 1.1 Example of aerobic exercise progress

Table 1.2 Components of FITT-VP

Components	What to have in an exercise prescription?
Frequency, *F*	How many days per week are reserved for the training session?
Intensity, *I*	How hard a person works to do the activity? The intensity of exercise can be determined according to objective criteria such as maximal heart rate, heart rate reserve, and maximum oxygen consumption, or it can be adjusted according to the effort perceived by the patient by using some scales. Absolute intensity refers to the amount of energy expended per minute of activity, while relative intensity takes into account a person's exercise capacity or cardiorespiratory fitness level to assess the level of effort. As a general rule, a person doing moderate-intensity aerobic exercise can talk but not sing during the activity. A person doing high-intensity aerobic exercise cannot say more than a few words without pausing for taking a breath (see Table 1.3 for definitions on assessment of aerobic exercise intensity)
Time, *T*	The length of activity or exercise is performed. Duration is usually expressed in minutes
Type, *T*	The type of exercise performed
Volume, *V*	The total amount of training load
Progression, *T*	The advancement and increase in exercise stimulus over time

Table 1.3 Aerobic exercise intensity measurement methods

Method	Explanation
METs	Metabolic equivalents (METs) are expressed in mL per 1 kg of the person's body weight of oxygen consumed in 1 min. It can be thought of as the energy expended or the amount of oxygen consumed during activity/rest • MET is the rate of energy expended at rest. It is traditionally taken as an oxygen intake of 3.5 mL per kg of body weight per minute • Light-intensity aerobic activity is activity at 1.1–2.9 MET, moderate-intensity activity at 3–5.9 MET, and vigorous activity at 6 and above MET The intensity of aerobic activities can also be measured simply as the speed of the activity (for example, walking at 5 km/h, jogging at 10 km/h)
VO_{2max}/VO_2R	Aerobic intensity as determined by exercise tests can also be expressed as a percentage of a person's maximum oxygen uptake/aerobic capacity (VO_2max) or oxygen uptake reserve (VO_2R)
%HR_{max}/%HRreserve	Aerobic intensity, which can be measured by maximum exercise tests or estimated by the person's age, can also be expressed as a percentage of a person's maximum heart rate (HRmax)[a] or heart rate reserve (HRreserve)[b]
RPE	Rated perceived exertion (RPE) can score how much difficulty a person feels when exercising

[a]HRmax can be estimated by subtracting age from 220 (classic Karvonen formula) or 206.9 − (0.67 × age) in individuals 19 years and older

[b]HRreserve = HRmax − HRrest, HRtarget = 0.6 HRreserve + HRrest

performed. The exercise type (*T*) applied together with the other components form the basic principle of the exercise prescription—FITT-VP principle. Definitions related to the FITT-VP principle are summarized in Table 1.2.

The intensity of aerobic exercise can be determined with scales assessing perceived effort by metabolic equivalents, percent of maximum heart rate or heart rate reserve, and percent of maximum oxygen uptake/aerobic capacity or oxygen uptake reserve (Table 1.3).

1.2.1.3 Volume

Volume refers to the total work done at a given stage of training. It includes the duration of the activity, the distance, and the number of times it is repeated during the training period.

1.2.1.4 Progression

Increasing the intensity, duration, frequency, or amount of activity or exercise while the human body adapts to a certain activity pattern is called exercise progression. An example of aerobic exercise progression is given in Fig. 1.1.

1.2.2 Muscular Strengthening Exercises

Muscular strengthening exercises make the muscles do more work than they usually do (overloading the muscles). If an exercise is of medium to high intensity and works major muscle groups of the body, such as legs, hips, back, chest, abdomen, shoulders, and arms, it is considered as a strengthening exercise. Resistance exercises, including weight training, are the best-known example of muscular strengthening exercises that can be prescribed using the FITT framework.

1.2.2.1 Scientific Basis

The force that the muscle can produce is determined by the cross-bridges that form in a sarcomere over some time. The dominant fiber type in the muscle can determine which sport to be successful in; fast-twitch muscle fibers (type 2) produce more force, so training these muscles is of particular importance in power sports. The amount of active motor units at a given time determines the force that the muscle can produce. There are three different motor units in the human body. Type I withstands high fatigue, has a lower activation threshold, contains fewer muscle fibers, and has low force production during contraction. Type IIa is also resistant to fatigue, has a higher activation threshold, and produces a higher force. Type IIb is easily fatigued, has a high activation threshold, innervates the largest number of muscle fibers, and produces the greatest force during contraction.

Maximal force generation is determined by the properties of the contraction. The arrangement of the muscle fibers, the contraction speed, and the traction angle also affect the force generation. The force increases as the cross-sectional area increases.

Tips

Force–velocity relationship: If a muscle changes in length, the force produced by the muscle changes
As the force increases further, the muscle does not allow shortening and contracts isometrically
As the shortening rate increases, the force decreases. In other words, to increase the force, it is necessary to slow down the contraction rate
If the external load on the muscle increases (more than the force the muscle can produce), the velocity becomes negative and the muscle contracts eccentrically (Fig. 1.2)

Likewise, the type of contraction also affects the amount of force generation. For example, in eccentric contraction, the external force applied to the muscle is greater than the muscle can exert. Calculating the difference between the maximum force generated by eccentric and isometric contraction provides the opportunity to design the most appropriate training program. When the force generated by the muscle during eccentric and isometric contraction is equal, we can assume that the muscle produces the best force according to its cross-sectional area. It is clear that the available muscle mass is underutilized when there is a significant difference between the maximum force produced during eccentric and isometric contraction.

Muscular strength training is motor unit training (Fig. 1.3). With muscular strength training, the number of motor units activated, and the firing power and duration of motor units improve. As a result, the resulting force increases. When all motor units are activated, 60–80% of the maximal contraction force occurs, depending on the type of muscle. The threshold for activation of motor units decreases with high-speed contractions.

The force generated in slow-speed contractions is three times greater than in high-speed contractions. Additional power is generated by the synchronization of the motor units. Adaptation to training occurs by agonist–antagonist muscle co-activation. This co-activation depends on the type of contraction, speed, and fatigue. All motor units can be activated at 30% of maximal contraction.

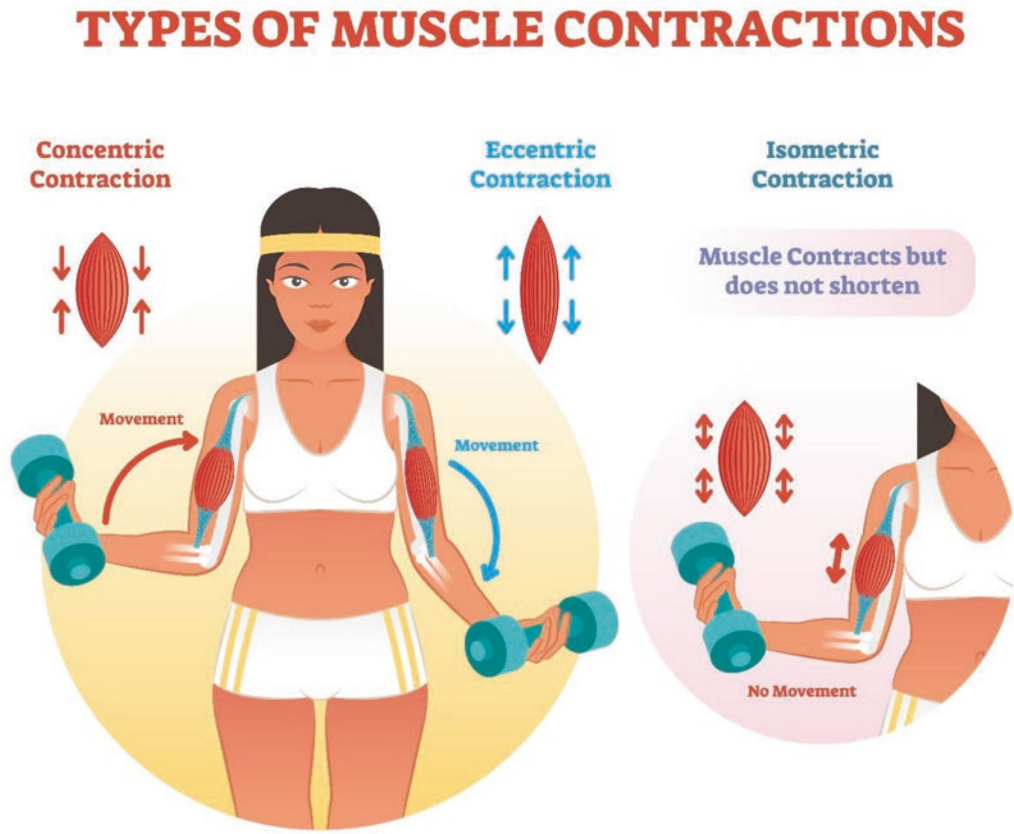

Fig. 1.2 Types of muscle contractions—concentric: visible movement occurs in the joint and the length of the muscle is shortened; isometric: no visible movement occurs in the joint and muscle tone increases, and activation of motor units is preset; eccentric: visible movement occurs in the joint and the muscle lengthens, and additional automatic activation is required (VectorMine/Shutterstock.com)

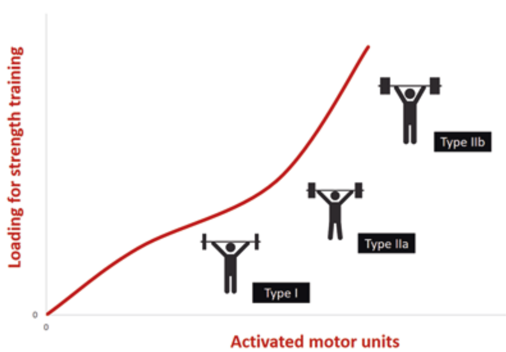

Fig. 1.3 The relationship between loading and motor unit activation (Alex Ghidan/Shutterstock.com)

Anabolic hormone production level also determines strength. Anabolic hormones include: growth hormone (GH), testosterone, and insulin-like growth hormone (IGF-1). (1) *Growth hormone* (GH) is released from the anterior lobe of the pituitary. It is released in the highest dose at night. GH targets organs (including muscle and liver) that stimulate the production of insulin-like growth hormone. After high-intensity physical training, the GH level increases after 10–20 min. The effect on the muscle is in the form of an increase in the cross-sectional area. (2) *Testosterone* is an anabolic hormone produced by the testes and, to a lesser extent, by the adrenal gland. Slow- and fast-twitch muscle fibers differ in testosterone sensitivity. Slow type I fibers show higher sensitivity, while fast IIb is less sensitive to testosterone. Long-term, low-intensity training reduces testosterone levels. Aerobic training provides its cardioprotective effect with a decreased testosterone level. After high-intensity training (over 70%), testosterone level remains high for 30–40 min. (3) *Insulin-like growth hormone (IGF-1)* is an anabolic hormone with a structure similar to insulin. It is generally produced by the liver and can be produced locally in the muscle if needed. IGF-1, like many hormones, works through receptors. Its main function is to promote protein synthesis. Since IGF-1 is a growth stimulant, chronically high levels increase the incidence of different types of cancer. So, a low IGF-1/insulin level means longevity. Long-term aerobic exercise lowers the level of IGF-1, while high-intensity exercise increases the level of IGF-1. IGF-1 level increases in muscle injury, and its anabolic effect increases healing and adaptation processes. Since the level of IGF-1 is closely related to GH production, its level decreases with age, similar to GH.

Before moving on to the prescription principles for muscular strengthening exercises, let us remember the definitions of strength, power, and endurance. The strength, power, or endurance of a muscle is the *ability* of the muscle. (1) *Muscular strength* is the ability to generate force against resistance. It is important to maintain the normal level necessary for a normal healthy life. Muscular weakness or imbalance impairs function. (2) *Muscular endurance* is the ability to produce repetitive muscular contractions against resistance. (3) *Muscular power* is the ability to build force quickly. Combination of force and speed, performance is limited without power.

Whichever is to be developed—muscular strength, power, endurance, and hypertrophy—it is necessary to focus primarily on the predominant criteria.

Tips

	Predominant parameters (respectively)
Muscle strength and hypertrophy	Loading–repetitions–speed of movement
Muscular power	**Single target:** speed of movement–loading–repetitions **Multi-target:** speed of movement–repetitions–loading
Muscular endurance	Repetitions–speed of movement–loading

1.2.2.2 Dosage

The dose of strengthening exercise is a combination of the frequency, intensity, and volume of the exercise performed. When prescribing resistance exercise to the patient, especially the dosage and type should be determined. Other explanations regarding FITT-VP training principles are summarized in Table 1.4. It is important to remember that every resistance exercise should be done with appropriate techniques. Individuals new to resistance exercises should be trained in all aspects before starting these exercises.

1.2.2.3 Volume

While lowering repetitions with a heavier load develops muscular strength and power, more repetitions with a lighter load improve muscular endurance (Fig. 1.4).

1.2.2.4 Progression

As the patient progresses, the exercise dose may be increased (overload) to improve muscle strength and endurance. Overload can be achieved by regulating several variables: (1) increase the load (or intensity), (2) increase the number of repetitions per set, (3) increase the number of sets per exercise, (4) decrease the rest time between sets or exercises, and (5) increase the frequency of exercise. It is recommended to increase the number of repetitions before increasing the load.

Table 1.4 Principles of strengthening exercise within the framework of FITT-VP

Key component	Details
Frequency, *F*	1. Number of days per week devoted to exercise specific to each muscle group 2. Depending on the individual's daily schedule, all muscle groups to be trained can be done in the same session (i.e., the whole body), or the body can be "divided" into selected muscle groups during each session so that only a few of them can be trained with the exercise done in any one session. For example: lower body muscles can be worked on Mondays and Thursdays, and upper body muscles on Tuesdays and Fridays (in this case, each muscle group will be worked 2 days a week)
Intensity, *I*	1. "Load" is the way to express the intensity of the prescribed resistance exercise. "Load" refers to the amount of weight or resistance in an exercise set 2. To estimate the limb-specific weight load for resistance exercise, 1 maximum repetition (1RM) can be determined, and then a certain percentage of that amount (i.e., 1%RM) can be used during each set of the exercise. 1RM: The greatest resistance/weight that can be moved in good posture and in a controlled manner throughout the entire range of motion, that is, the maximum amount of weight that can be lifted once for a given exercise that cannot be lifted a second time
Time, *T*	1. While a specific amount of time is not recommended for resistance exercise, repetitions and sets are the standard way to refer to the amount of work needed in an exercise prescription 2. "Repetitions" is the performance of a single exercise, like lifting a weight once 3. A "set" consists of non-stop repetitions. A reasonable rest interval between sets is 2–3 min, but a shorter interval may be allowed for low-intensity training (mainly to improve muscular endurance rather than strength and mass). For example: 1 set = 12 times of continuous weight lifting 4. The number of repetitions and resistance performed in each set is inversely proportional to the load of your exercise, meaning the greater the load, the fewer repetitions that need to be completed
Type, *T*	1. The form of exercise 2. Exercise regimens should include multi-joint or combined exercises. The resistance of multi-joint or combined exercises can be changed with exercise equipment, body weight, or load-bearing
Volume, *V*	1. Exercise volume or quantity is the product of Frequency, Intensity, and Time. 2. Cardiorespiratory fitness volume can be calculated by how many steps you walked weekly. 3. Resistance exercises volume is calculated by sets and repetitions. . 4. The recommendation for resistance exercise is 2-4 sets with 8-12 repetitions per set with 2-3 minutes rest intervals.
Progression, *P*	1. It is best to increase intensity first then time/duration. 2. For cardiovascular training: a. Increasing any of the FITTV categories. b. To reduce the risk of injury, start low and go slow. 3. For resistance training: It is best to gradually increase the resistance, and/or more repetitions per set, and/or increased the frequency of workouts. Progression can be thought of as stairs and the railing of the stairs as the FITT-VP model. If the railing is used as a support, it is safer and faster to reach the top.

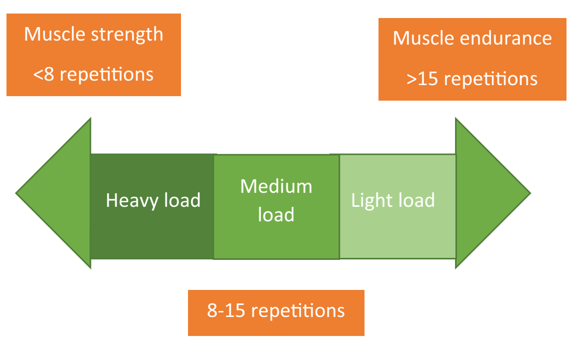

Fig. 1.4 The relationship between repetitions and loading

Training loads can be increased (e.g., ~5%) when the patient can comfortably reach the “upper limit” of the predetermined repetition range, for example, 12–15 repetitions.

1.2.2.5 Strength Training Methods

In training, it needs to be focused on exercises that improve neuromuscular coordination to activate more motor units and synchronize activations. The methods that are frequently used as strength training methods are: *maximal strength training*, *explosive strength training*, and *endurance training*. These methods are described in detail below.

Maximal Strength Training

The maximal strength value is important in all sports because its value affects both explosive power and endurance. Maximum strength reaches its peak at the age of 20–35 in men and 18–30 in women. Maximal strength is developed in two ways: (1) high muscle tension exercises, and (2) high-speed exercises. Maximal strength develops if there are only one to two repetitions in a set. This is the result of adequate motor unit activation and synchronization. The most popular maximal strength development method is high-intensity moderate-resistance exercises (60–70% of 1RM, 6–8 repetitions, 6–8 sets) in the first phase, followed by high-intensity and low-repetition exercises (90–100% of 1RM, 1–3 repetitions, 3–5 sets) (1RM: 1 maximum repetition). If there is more than one goal during a single workout (for example, increasing both maximum strength and endurance), then exercises aimed at developing maximum strength should be planned first.

The following methods are frequently used for maximal strengthening training: (1) *pyramid method*, (2) *isometric training*, (3) *muscle cross-sectional development method*, (4) *eccentric training*, (5) *mid-level submaximal and maximal resistance training*, and (6) *isokinetic training*. (1) *Pyramid method* is based on the principle of continuously increasing the resistance from 60% to the maximum level and then gradually decreasing it. During this training, the large muscle tension necessary for muscle hypertrophy occurs. This method is also suitable for maximum speed exercises (at 60–70% resistance). Activation of fast-twitch motor units is achieved by this method. Due to the high intensity of exercise, anabolic hormone adaptation develops. In this training, mainly concentric contractions occur and 1–3 min of rest is required between sets. (2) *Isometric training* can be performed throughout the joint movement as pain permits. When a true maximal voluntary isometric contraction is performed, it creates more strength gain than a concentric contraction. It provides the opportunity to work within the defined weak joint range of motion, positively affects physical performance, and prevents injuries. Isometric contractions create an acute analgesic effect by changing the excitation/inhibition cycle in corticomotor pathways, thus facilitating dynamic loading. It is a reliable technique for evaluating and monitoring changes in power generation. The tension created by isometric contractions stimulates satellite cells and ensures the formation of new nuclei and muscle growth by splitting muscle fibers. (3) *Muscle cross-sectional development method* is suitable for strength development since there is a close relationship between cross-sectional area and strength. The basic concept consists of working out several repetitions and series with maximal loading (e.g., 70%, 6 × 6 repetitions). Tension stimulates satellite cells and splits muscle fibers, resulting in both the formation of new nuclei and the transverse expansion of the muscle. (4) *Eccentric training* is applied via eccentric contraction occurring when the force produced inside the muscle is less than the force applied externally to the muscle, causing an actively controlled lengthening of the muscle fibers under load. In direct comparison, eccentric muscle contraction can generate more force. Lower levels of neural activation are used for 20–60% higher force compared to concentric contraction. The maximum force is released during maximal eccentric contraction due to high loading. This feature allows for training with light weights. Additional neural gains are achieved during an eccentric contraction, such as greater excitability and influencing a larger brain area. In eccentric training, energy consumption is lower despite the high muscle strength. It creates less fatigue. Muscle damage caused by eccentric training is more in the upper extremity. (5) *Intermediate submaximal and maximal resistance training* is formed by mechanisms activated by high resistance. With eccentric and isometric contractions, it is aimed to increase not only the amount of contracted fiber but also the amount of connective tissue. Tendons connect muscles to bones and store forces produced by sarcomeres. Collagen and elastin have a long life (more than 200 days). The synthesis of connective tissue is slower compared to the contractile structures of the muscle we target in muscle hypertrophy. This training mainly aims to reduce the risk of injury, which is very common at muscle–tendon junctions. Combined eccentric and isometric contractions increase the amount of both contracted fiber and connective tissue. (6) *Isokinetic training* is performed at a constant speed using special machines. Muscle growth occurs thanks to near-maximal tension during exercise.

Clinical Tips

Isometric training	Can change muscle architecture, tendon properties, power generation at significant angles, and metabolic functions
Isometric training	Can be done at different joint angles by varying the contraction duration/intensity
Isometric contractions should be performed in two ways: "push" toward an immovable object and "hold" the joint in position while resisting external force	
The maximum isometric force is related to the maximum dynamic force. It should be close to 90–100% of 1RM. If we cannot measure: 8–12 s/6 × 8 repetitions for 100%, should be done	
Example formula: 100% of maximal voluntary contraction/8–12 s/6 × 8 repetitions	

Important Note

Four techniques are often used in eccentric training	
2/1 technique	After concentric movement on both extremities, return is made with eccentric movement with one extremity. The loading should be as fast as possible in the concentric phase and as hard as possible during the eccentric phase. The load in the eccentric phase should be twice that of the concentric phase. Also, 70% of 1RM is enough for a start. Sets of 3–5 repetitions per limb (6–10 total repetitions per set) are performed with a 60-s rest interval
Two-movement technique	It is very technical and difficult to implement. In the two-movement technique, it is recommended that the concentric part be a multi-joint exercise in preparation for the isolated eccentric part. Intensity and load criteria: 5-s eccentric (5 repetitions/4–5 sets) should consist of 90–110% of 1RM. Rest periods should be 1–2 min between sets
Slow/superslow technique	It is a relatively simple technique. The eccentric phase is very slow. The amount of loading is very important in this technique. At low rates of 1RM, long eccentric loading (60%, 10–12 s) gives the same response as 85%, 4 s of eccentric loading. Depending on the amount of load, the type of movement, and the size of the muscle group: 60–85% of 1RM can be done for 2–15 s. A rest period of 60 s is commonly used

Negative (supramaximum) technique	It must be done under the supervision of 1–2 people. In 110–120% of 1RM, 1 concentric contraction is followed by an eccentric contraction for 8–10 s. In 125–130% of 1RM, 1 concentric contraction is followed by an eccentric contraction for 4–5 s

Explosive Strength Training (Plyometrics)

Plyometric exercises aim to activate and synchronize as many motor units as possible. Unlike maximal strength training, which targets muscle growth, the goal in plyometrics is to reach maximum speed. Special situations where the potential rate of contraction of the muscle is higher, such as pre-tension, rapid relaxation contractions, and reactive movements, are beneficial for this type of exercise. A plyometric training consists of three phases: (1) eccentric phase (loading), (2) transition phase (conversion), and (3) concentric phase (no loading).

This training improves the connective tissue of the muscles and, as a result, there are no problems with high-speed movement. Fatigue should not be created in this training. Therefore, rest is very important. With plyometric training, fast-twitch fibers get very tired and are therefore almost impossible to reactivate. Plyometric training is designed to teach more motor units to synchronize when fatigue occurs. Whatever happens during burst strength training, it is necessary to focus on exercising at a maximum speed independent of resistance. In short, speed–strength exercises should be planned at the beginning of the training, right after the warm-up period. Example: 4 s (eccentric phase)—0 s (wait)—2 s (concentric phase)—0 s (wait) or 4 s (eccentric contraction)—0 s (hold in tense position)—1 s (concentric contraction)–0 s (hold in short position).

Important Note

Three techniques are often used in explosive strength training	
Dynamic variable resistance method	Goal: Do the exercises at 30–80% of maximum strength. It should be done at a low number of repetitions and maximum speed so that the fast-tiring muscle fibers do not get tired. When we stand up from 90° knee flexion with maximum speed and 60% of body weight with 5 × 3 repetitions, it does not enlarge the muscle but develops neural adaptation against fatigue. Although resistance is added in the future, the level of training that keeps the speed at its maximum and does not cause fatigue should not be surprising
Quick-relax contractions	This method combines isometric and concentric contractions. At the beginning of the exercise, isometric contractions are performed for 3–5 s to increase the tension created by shortening the contractile elements of the muscle and lengthening the elastic elements of the muscle at any angle. Thus, the muscle can contract at maximum speed. This training method perfectly improves neuromuscular control, as a large number of motor units are engaged. Because of the fast-twitch fibers, this exercise should also be given at low resistance and with ample rest intervals
Reactive training	In this training, the eccentric contraction starts from the longest position of the muscle. The muscle accumulates the mechanical energy generated by eccentric contraction, and muscle shortening accelerates even more. This technique can be used in activities such as jumping from a step, jumping the bar, or throwing a ball. Fatigue should be noted during this type of exercise because large muscle contractions and speed carry a higher risk of injury

Endurance Training

It involves prolonged exertion with moderate resistance. It is very important for sports played with the ball, martial arts, middle and long-distance running, cycling, canoeing, and swimming. In designing endurance training, we must be very careful about what sport or activity the person is doing. For example, a tennis player must be given the endurance to hit the ball at 200 km/h even in the fifth hour. Different endurance training programs should be planned for each of the athletes performing wrestling, swimming, and so on.

Important Note

Two techniques are often used in endurance training	
Low-resistance training	This training is most popular for building endurance (30–50% resistance, 20–50 repetitions, and 8–20 sets). The resistance and the number of sets should be designed individually. Contrary to speed–strength training, exercises in this training should be continued until fatigue develops. During these exercises, fast-twitch fibers may be required as well as slow-twitch fibers. With this technique, intense lactic acid accumulation occurs
Circular training	The targeted muscle can be loaded with the exercise equipment in the station. The ratios to exercises performed with body weight are insufficient in the training of rotational movements. High repetitions and low load (30–50%) should be used. Intense lactic acid accumulation should not be forgotten

1.2.3 Stretching Exercises

It is a therapeutic exercise maneuver that uses physiological principles. It is designed to increase joint range of motion or the extensibility of pathologically shortened connective tissue structures. Stretching exercises increase flexibility, allowing the easier performance of activities that require flexibility. These exercises are a reasonable part of the exercise program and it is not clear whether they reduce the risk of injury. Stretching exercise techniques that are frequently used are given in Table 1.5.

The active stretch of the muscle is determined by alpha and gamma innervation, while the passive stretch is determined by the viscoelasticity of the muscle and the properties of the fascia. Connective tissue exhibits viscoelasticity, which combines flexibility and viscosity properties. Elasticity is the ability of a material to return to its original state (length or shape) after stress or

Table 1.5 Stretching types

Types	Details
Static	It involves voluntary passive relaxation while the muscle is extended
Dynamic	The movement is not held in the final position and involves swinging, bouncing, or rocking during stretching
Active	It involves the active contraction of the agonist's muscle while the antagonist muscle group is stretched
Slow	It involves slow movements of the muscle that are active in situations such as lateral neck flexions, arm rotations, and trunk rotations
Proprioceptive neuromuscular facilitation (PNF)	PNF involves isometric contraction of the muscle after static stretching followed by a greater passive stretch

Table 1.6 Some stretching types and application details used in the clinics

Types	Details
Static stretching	• Slow stretching of the muscle up to the range of motion • A moderate tension should be felt • There should be little or no pain • It is applied in two ways: active static and passive static
	1a. Active static stretching: • Should be active • The tension of the agonist should help the antagonist to relax • Same tension-type in Pilates and Yoga
	1b. Passive static stretching: • Should be done in a completely relaxed position • The shortened tissue should be lengthened manually or with other equipment • Before passive stretching, there must be a cool-down phase • Used for post-exercise fatigue and muscle aches
Dynamic stretching	• It is a type of stretching in which springing and swinging movements are also used, within the soft and controlled range of motion limits • Jumping and sudden movements will never happen • It is used for heating purposes • It should be stopped when fatigue occurs • Once every 2 s/15 repetitions/2 sets/day
Ballistic stretching	• It is repetitive, sudden jumping, springing, or forced loading of movement on tensed muscles • It may cause injury • Not suitable for use on injured tissues

load is removed. This changeable property is called *elastic deformation* and is similar to the changes that occur in a rubber band under high strain rates. The rubber band quickly adapts to a new length and can return to its original resting length when the stress is relieved. Stretching types and application details frequently used in clinics are summarized in Table 1.6.

Skeletal muscle adapts acutely and chronically to exercise, stretching, and loading. The acute effects of stretching exercise are an increase in normal joint range of motion and connective tissue mobility. Chronic effects are in the form of a decrease in the motor neuron pool (especially affected by large- and low-amplitude stretching) and moderate sarcomere increase.

Considering the effects of stretching exercise on physical performance, static and proprioceptive neuromuscular facilitation (PNF) stretches performed just before exercise/training (instant effect) affect physical performance negatively (muscular strength decreases), while the instantaneous effect of dynamic stretching is positive (muscular strength increases). The long-term effect of static stretching is to improve performance. Stretching exercises in addition to muscle strengthening exercises are more effective in increasing strength.

Clinical Tips

To get a maximum normal range of motion	Static stretching: 15–30 s
To increase flexibility and lengthen the muscle	2–4 repetitions of static stretching for 10–30 s
Ideal technique for dynamic stretching	15–30 s/2–3 repetitions/2–3 days
The most suitable stretching method used for warming-up in running and jumping	Dynamic
The most suitable stretching method used for warm-up in dance and ballet	Static
Stretches longer than 30 s	Are not recommended as they reduce blood circulation in the tissue

1.2.4 Neuromuscular Exercises

Neuromuscular fitness exercises should be included in the exercise prescription to improve balance, agility, and proprioception. Neuromuscular control is defined as the unconsciously trained response of a muscle to a signal related to dynamic joint stability. Extremity movements are controlled through this system, which should provide the correct information for purposeful movement. Neuromuscular training programs should cover all aspects of sensorimotor function and functional stabilization to improve function and alleviate the patient's symptoms.

Neuromuscular training is based on biomechanical and neuromuscular principles and aims to both improve sensorimotor control and provide compensatory functional stability. Unlike traditional strength training, neuromuscular exercise addresses the quality of movement and aims to achieve joint control in all three planes of motion.

Neuromuscular exercise has many effects such as improving functional performance, biomechanics, and activation of periarticular muscles. Simply, the recovery of mechanical limitations is not sufficient for the functional recovery of a joint, because the coordinated neuromuscular control mechanism required during daily life and sports-specific activities cannot be developed to the desired level in this way.

Exercise programs cannot change mechanical joint instability, but can improve neuromuscular control and dynamic joint stability. Delay in neuromuscular reaction time can cause dynamic joint instability with recurrent joint subluxation/dislocations. Therefore, both mechanical stability and neuromuscular control are critical in achieving a long-term functional outcome, and both aspects should be considered in the design of a neuromuscular rehabilitation program. Sensorimotor control or neuromuscular control is the ability to produce controlled movement through coordinated muscle activity. Functional or dynamic stability is the ability of the joint to remain stable during physical activity.

Neuromuscular training programs are effective in improving function and reducing symptoms in people with joint problems. Neuromuscular exercises involve multiple joint and muscle groups performed in functional weight-bearing positions. Neuromuscular exercises aim to ensure the quality and efficiency of the movement and the proper alignment of the trunk and joints during movement.

Exercises to improve sensorimotor control are performed in different (lying, sitting, standing) closed kinetic chain positions to achieve low, evenly distributed joint surface pressure by muscle co-activation. Sensorimotor functions such as coordination, agility, balance, and proprioception are the components of neuromuscular exercise. The aim is to balance the loaded segments in static and dynamic situations and to provide postural control in activities of daily living or more challenging sports activities. Efficiency and quality of movements should be emphasized during neuromuscular exercise.

Tai Chi, Pilates, Yoga, and Otago exercise programs on balance platforms are frequently used in coordination and balance-focused exercises. Agility exercises are also an important part of neuromuscular training.

1.2.4.1 Coordination Exercises

A coordinated movement has three criteria

1. *Will*: The ability to initiate, maintain, or stop an action.
2. *Perception*: It is the ability to harmonize motor stimulation and sensory feedback in proprioception and subcortical centers. When proprioception is affected, the patient tries to compensate with visual feedback.
3. *Memory*: The putative physical or biochemical change in neural tissue represents a memory. Developing memory should be done with high repetitions of performance. Memory and coordination develop in proportion to the number of repetitions performed just below the maximum level of the individual's ability to perform a movement.

General principles of coordination exercises

1. Several motor activities must be repeated over and over.

2. Sensory stimuli (tactile, visual, proprioceptive) should be used to increase motor performance.
3. The speed of activity should be increased over time.
4. Exercises should initially be broken down into components that are simple enough to perform correctly.
5. Provide support only when needed.
6. Take a short rest after two or three repetitions to avoid patient fatigue.
7. Performance must be done with high repetition for memory formation.
8. When a new movement is trained, various inputs should be given, such as instruction (auditory), sensory stimulation (touch), or positions where the patient can see the movement to improve motor performance (visual stimulation).

1.2.4.2 Balance Exercises

Balance training is use of exercises for the antigravity muscles to increase stability. Most geriatric patients should be included in their treatment plan as it prevents falls, the second cause of accidental or unintentional injury deaths worldwide. Balance exercises are also effective in improving postural and neuromuscular control.

Reactive balance training (RBT) improves control of certain reactions to correct impaired balance and prevent falls. Reactive balance training has the potential to improve many aspects of physical health simultaneously. It can be improved with internal and external perturbation techniques. Internal perturbation occurs when the patient cannot adequately control the center of body mass while performing an expected activity. External perturbation occurs when the force acting on the center of mass causes the center of mass to move and reach or exceed stability limits in the environment outside the patient.

General principles of balance exercises

1. The activity must be at an intensity level that compels patients to react to prevent falls.
2. Exercises should include controlling internal and external perturbations.
3. Exercises should be progressively challenging.
4. The activity needs to be done repeatedly until the patient responds adequately.

1.2.4.3 Agility Exercises

Agility exercises improve the ability to change direction and make position transitions quickly. Agility training should include components such as strength, speed, power, flexibility, and dynamic balance. Agility training provides (a) braking of movement, (b) controlled execution of explosive movements, and (c) sudden and rapid displacement of body weight.

For a better and appropriate agility training

1. *Create explosive moves.* The development of explosive contractions allows an athlete to accelerate and decelerate the movement in a short time in a coordinated manner.
2. *Reduce reaction time.* Response time includes both information processing and the ability to act quickly. When an athlete reacts to an opponent's actions, they must quickly review options, decide on how to react, and then move in the appropriate direction. Mental processing can be accelerated in practice with techniques such as narrowing down choices, learning to anticipate, identifying cues, and visualizing appropriate responses.
3. *Efficient movement mechanics should be used.* Changing direction under control means athletes must quickly break or redirect momentum. It requires the development of dynamic stability to shift the center of gravity in different directions and maintain posture while reversing positions. Agility training teaches improving physical fitness, controlling the center of gravity, shifting the weight in a specified direction, and combining it with mental training to use mechanics-based strategies.
4. *Increase joint stability.* Training should prepare an athlete's joints for the agility of a sport. Injuries inherent in sports can be minimized or prevented with joint training.
5. *Increase trunk strength.* Adequate trunk strength and stability are required when changing weights, reaching, and bending, especially when changing direction quickly.
6. *Increase flexibility.* During agility training, flexibility is required to move easily through long ranges of motion.

Table 1.7 Sets, repetitions, load level, intensity, and rest intervals for muscular endurance, strength, power, hypertrophy, and peak torque gains

	Muscular endurance	Hypertrophy	Muscular strength	Power	Peak torque
Sets	1–3	2–4	2–5	3–5	1–3
Repetitions	12–20	8–12	4–8	3–5	1–3
Loading	Moderate	High	High	High	Low
Intensity	Low	Low	Low–high	Low–moderate	Very high
Rest intervals	30–60 s	60–90 s	150 s–5 min	3–5 min	5–8 min

1.3 Conclusion

Appropriate exercise training, as well as exercise selection, will determine the targeted muscular fitness. At the same time, the rest periods that should be given between exercise sets are also critical (Table 1.7). The movements used by the person in his daily life must be included in the exercise program. Performing the exercise training with the appropriate method, function-specific goal, and generally in the closed kinetic chain position (with body weight) will increase the success and the targeted gains.

Further Reading

Ageberg E, Roos EM. Neuromuscular exercise as treatment of degenerative knee disease. Exerc Sport Sci Rev. 2015;43(1):14–22.

Alsouhibani A, Vaegter HB, Hoeger BM. Systemic exercise-induced hypoalgesia following isometric exercise reduces conditioned pain modulation. Pain Med. 2019;20(1):180–90.

Coffey VG, Hawley JA. Concurrent exercise training: do opposites distract? J Physiol. 2017;595(9):2883–96.

Del Vecchio A, Casolo A, Negro F, Scorcelletti M, Bazzucchi I, Enoka R, Felici F, Farina D. The increase in muscle force after 4 weeks of strength training is mediated by adaptations in motor unit recruitment and rate coding. J Physiol. 2019;597(7):1873–87.

Douglas J, Pearson S, Ross A, McGuigan M. Eccentric exercise: physiological characteristics and acute responses. Sports Med. 2017;47(4):663–75.

Hellsten Y, Nyberg M. Cardiovascular adaptations to exercise training. Compr Physiol. 2015;6(1):1–32.

Hippocrates. Hippocrates. Cambridge: Harvard University Press; 1931. p. 229.

Hughes DC, Ellefsen S, Baar K. Adaptations to endurance and strength training. Cold Spring Harb Perspect Med. 2018;8(6):a029769.

Ketelhut S, Ketelhut RG. Type of exercise training and training methods. Adv Exp Med Biol. 2020;1228:25–43.

Konopka AR, Harber MP. Skeletal muscle hypertrophy after aerobic exercise training. Exerc Sport Sci Rev. 2014;42(2):53–61.

Lepley LK, Lepley AS, Onate JA, Grooms DR. Eccentric exercise to enhance neuromuscular control. Sports Health. 2017;9(4):333–40.

Lundby C, Jacobs RA. Adaptations of skeletal muscle mitochondria to exercise training. Exp Physiol. 2016;101(1):17–22.

Pedersen BK, Saltin B. Exercise as medicine—evidence for prescribing exercise as therapy in 26 different chronic diseases. Scand J Med Sci Sports. 2015;25(Suppl 3):1–72.

Physical Activity Guidelines Advisory Committee. Part C. Background and key physical activity concepts ve Part F. Chapter 1. Physical activity behaviors: steps, bouts, and high-intensity training. In: 2018 Physical Activity Guidelines Advisory Committee, editor. 2018 Physical Activity Guidelines Advisory Committee Scientific Report. Washington, DC: U.S. Department of Health and Human Services; 2018.

Ruegsegger GN, Booth FW. Health benefits of exercise. Cold Spring Harb Perspect Med. 2018;8(7):a029694.

Wewege MA, Thom JM, Rye KA, Parmenter BJ. Aerobic, resistance or combined training: a systematic review and meta-analysis of exercise to reduce cardiovascular risk in adults with metabolic syndrome. Atherosclerosis. 2018;274:162–71.